

# Feasibility of a 100 year Reanalysis using only Surface Pressure Data

Gilbert P. Compo, Jeffrey S. Whitaker,  
and Prashant D. Sardeshmukh

U. Of Colorado, CIRES

NOAA Earth System Research Laboratory,

Physical Sciences Division

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Download from <http://www.cdc.noaa.gov/people/gilbert.p.compo/Compoetal2005.pdf>

# Motivation

1. Would like to determine storminess and blocking variations over last 100 years. Currently available analyses are error-ridden hand-drawn SLP maps that do not make use all observations.
2. We should be able to do better with modern data assimilation systems.
3. Reanalyses with a fixed assimilation system are valuable for climate studies but varying observation networks introduce spurious climate variability.
4. Prior to 1948, few radiosondes are available, but newly recovered surface pressure observations raise the possibility of generating useful reanalyses of the lower tropospheric circulation.

# Previous work

Whitaker et al. (2003, 2004) showed surface pressure observations will produce “good” 6-hourly analyses of Northern Hemisphere SLP and 500 mb heights using ensemble Kalman filter.

Anderson et. al. (2005) used primitive equation model and ensemble filter with similar results.

Thepaut and Simmons (2003) used operational ECMWF 4D-Var with similar results.

Bengtsson et al. (2004) and Kanamitsu and Hwang (2005) concluded that surface observations are unable to produce reliable fields aloft using ERA-40 and NCEP-DOE 3D-Var systems.

Note that the first guess error statistics were assumed to be the same as in the modern era.

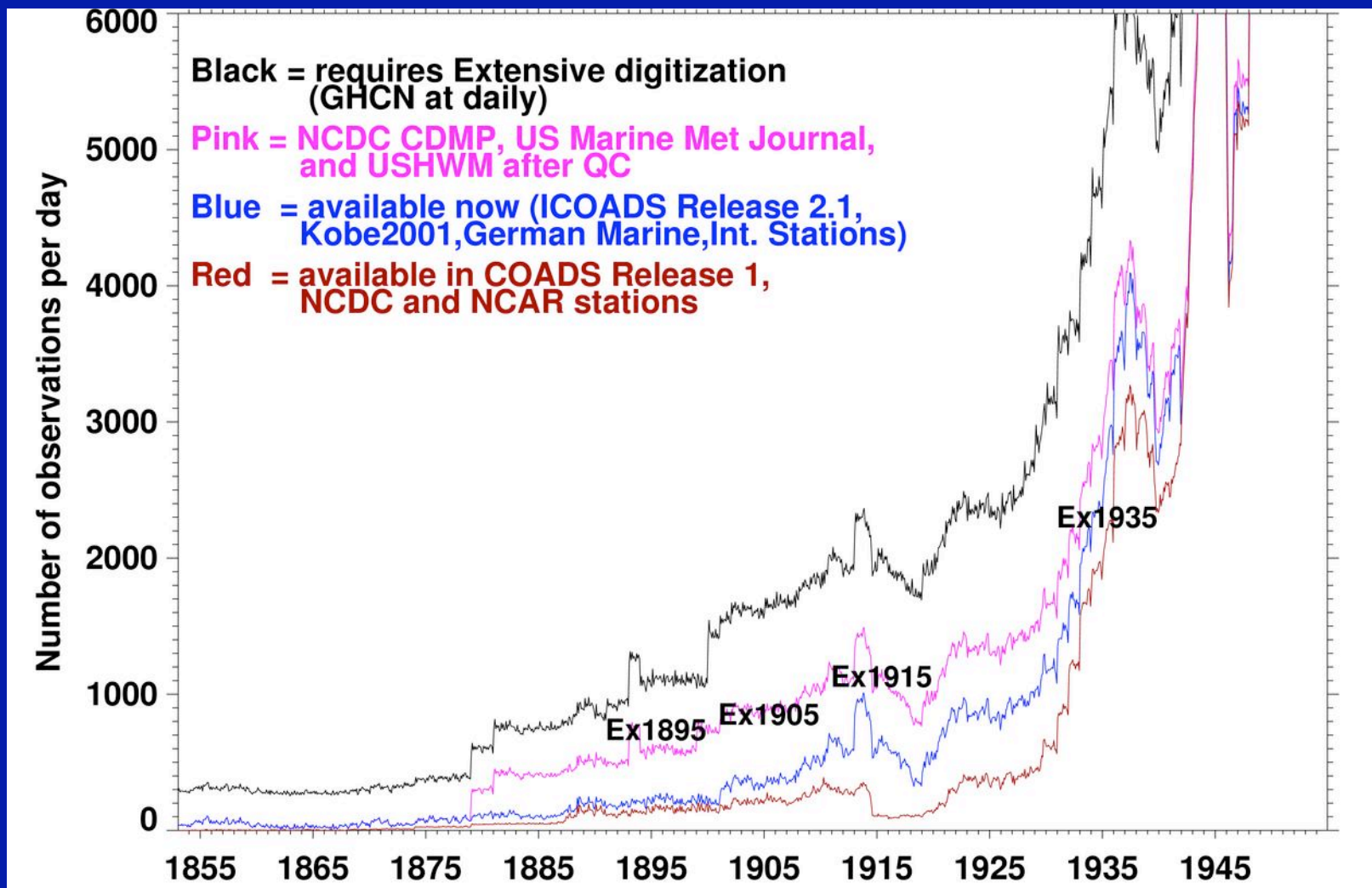
# Experiment

1. In every  $5^{\circ} \times 5^{\circ}$  degree box, use **only surface pressure** observations for 2001 at densities typical of 1895, 1905, 1915, and 1935.
  - No aircraft, balloon, satellite, or radiosonde data.
  - **100 times fewer** surface observations every 6 hours than currently used.

$$\text{Analysis} = \text{Background} + \text{Weight} * (\text{observation} - \text{Background})$$
2. With these reduced observational densities, make 6-hourly assimilations for 2001 using:
  - a) The NCEP-NCAR CDAS with **fixed** “first-guess” error statistics derived from the NCEP medium range forecast model (MRF) tuned for surface pressure only.
  - b) An Ensemble square root filter (EnsFilt) with the mean of a 100 member ensemble from MRF as the first-guess and the **time-varying** ensemble covariance as the error in that first-guess (Whitaker and Hamill, 2002).
  - c) An Ensemble Climatology Filter (EnsClim) with climatological mean as the first guess and anomaly covariances as the error statistics of that first guess.
3. Compute error relative to the Full NCEP-NCAR reanalysis CDAS (Kalnay et al. 1996) and compare to 1979-2001 MRF re-forecasts (Hamill et al. 2004).

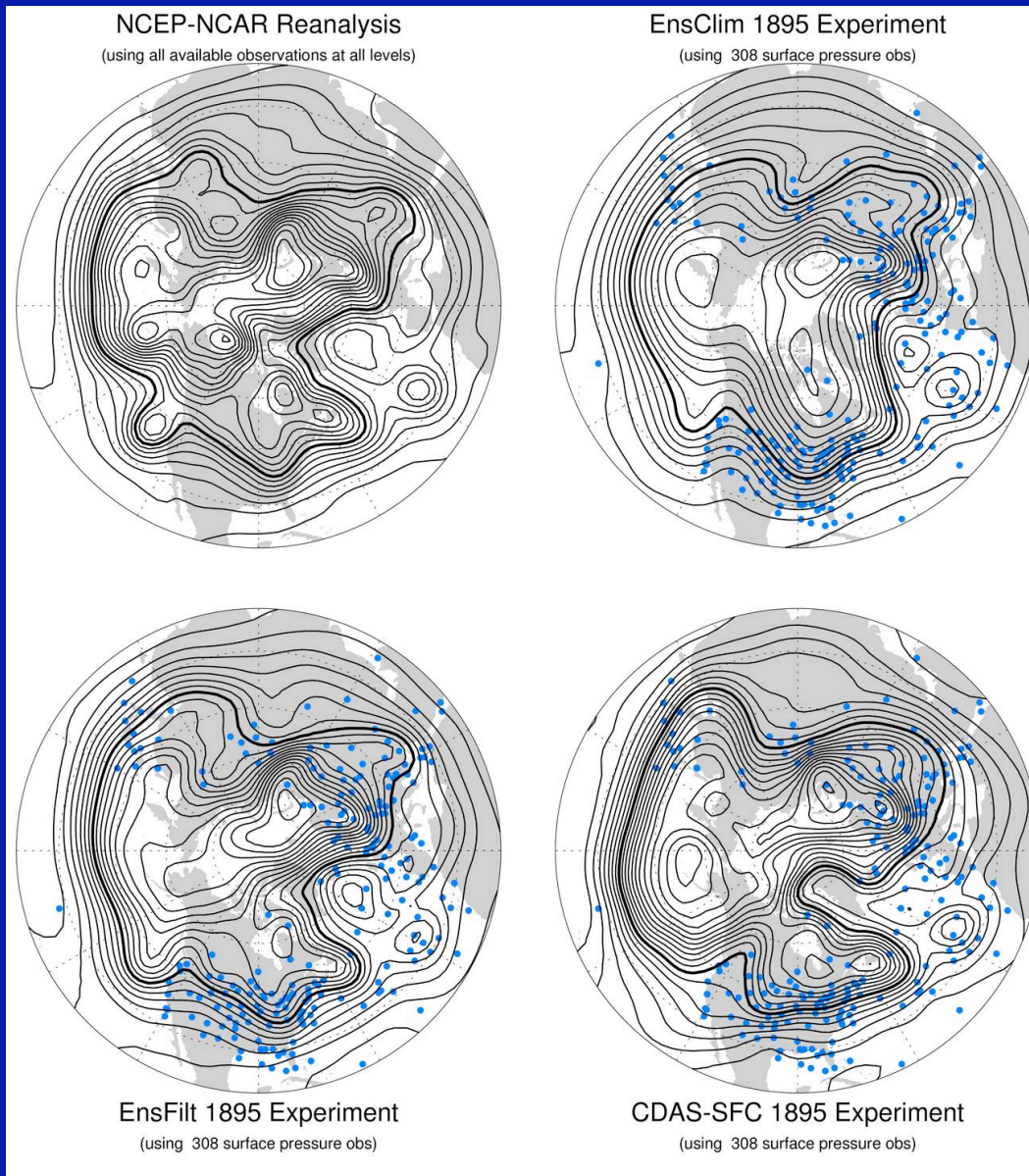


# Number of historical surface pressure obs in each month (1855-1954) poleward of 20N



# 500mb Height Analyses for 0Z 20 Dec 2001

Full CDAS  
(120,000+ obs)



EnsClim 1895  
(308 surface  
pressure obs)  
RMS = 96 m

EnsFilt 1895  
(308 surface  
pressure obs)  
RMS = 49 m

CDAS-SFC 1895  
(308 surface  
pressure obs)  
RMS = 96 m

5500 m contour is thickened

# RMS Error and Anomaly Correlation Skill of 6-hourly geopotential height analyses using CDAS-SFC, Ensemble Filter, and Ensemble Climatology Filter and Surface Pressure Obs at 1895 densities

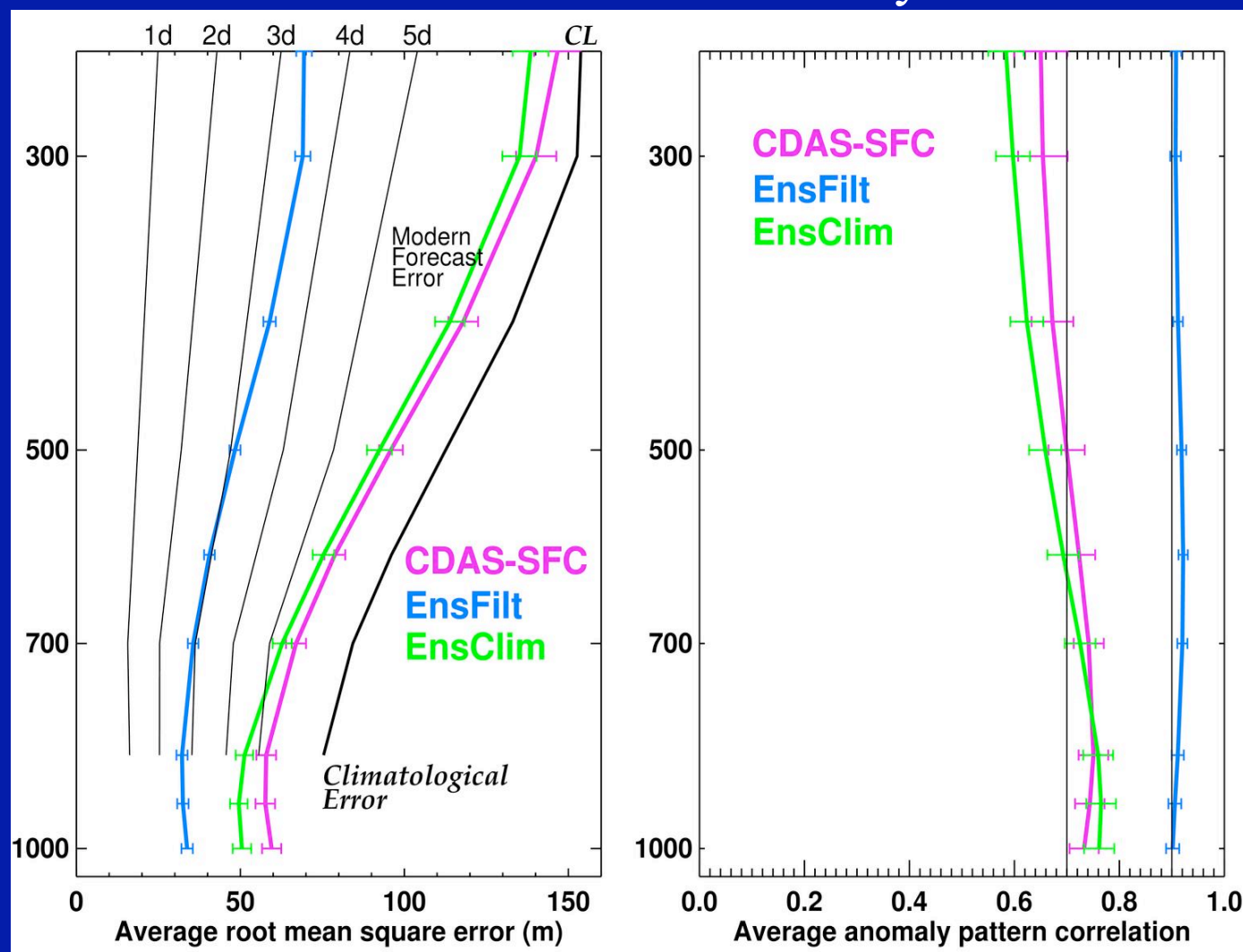
RMS

anomaly correlation

Surface pressure obs alone produce a good 6-hourly analysis even at 1895 densities.

Results obtained using **EnsFilt** are significantly better than the traditional CDAS-SFC.

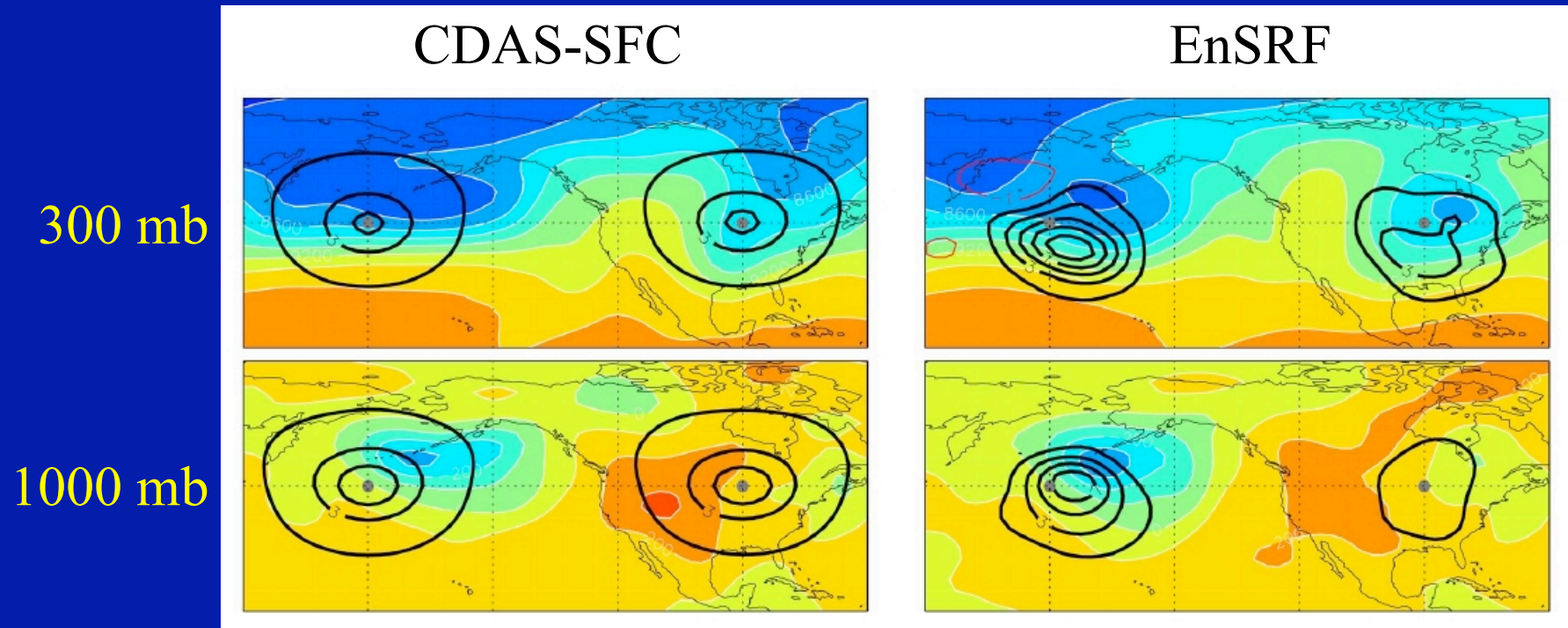
Expected error for 1895 circulation is comparable to a 3-day forecast error.



Simulating December 2001



**Geopotential height first guess and analysis minus first guess  
for single pressure observations 1mb greater than first guess**

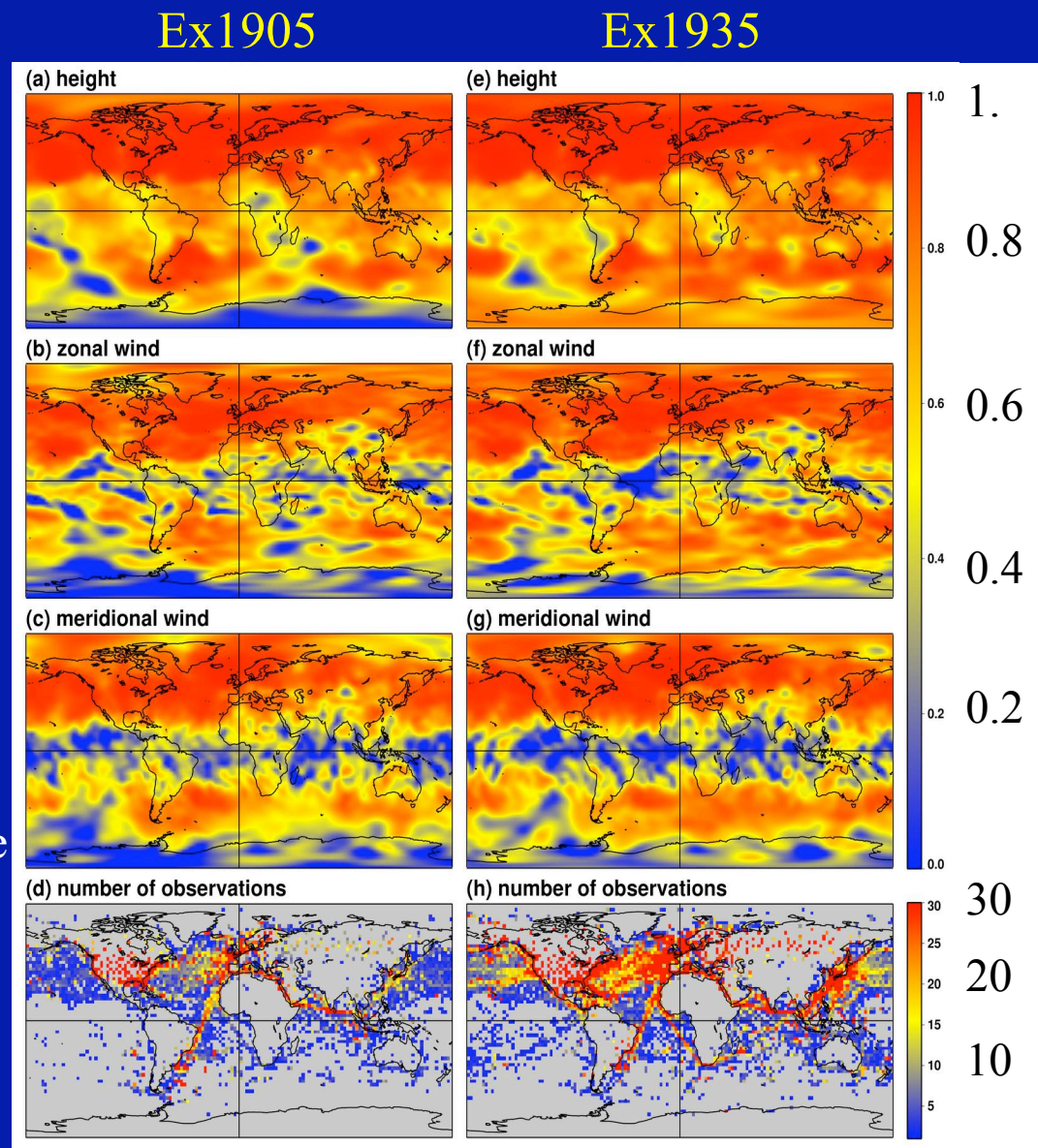


# Anomaly correlation skill of 700 hPa analyses using Ensemble Filter and only surface pressure observations

Extratropical Northern Hemisphere mass and wind fields are well-recovered despite inhomogeneous observation network.

Tropical mass field is recovered with the 1935 network, but wind field is not with either network.

More observations help extratropical Southern Hemisphere analyses.



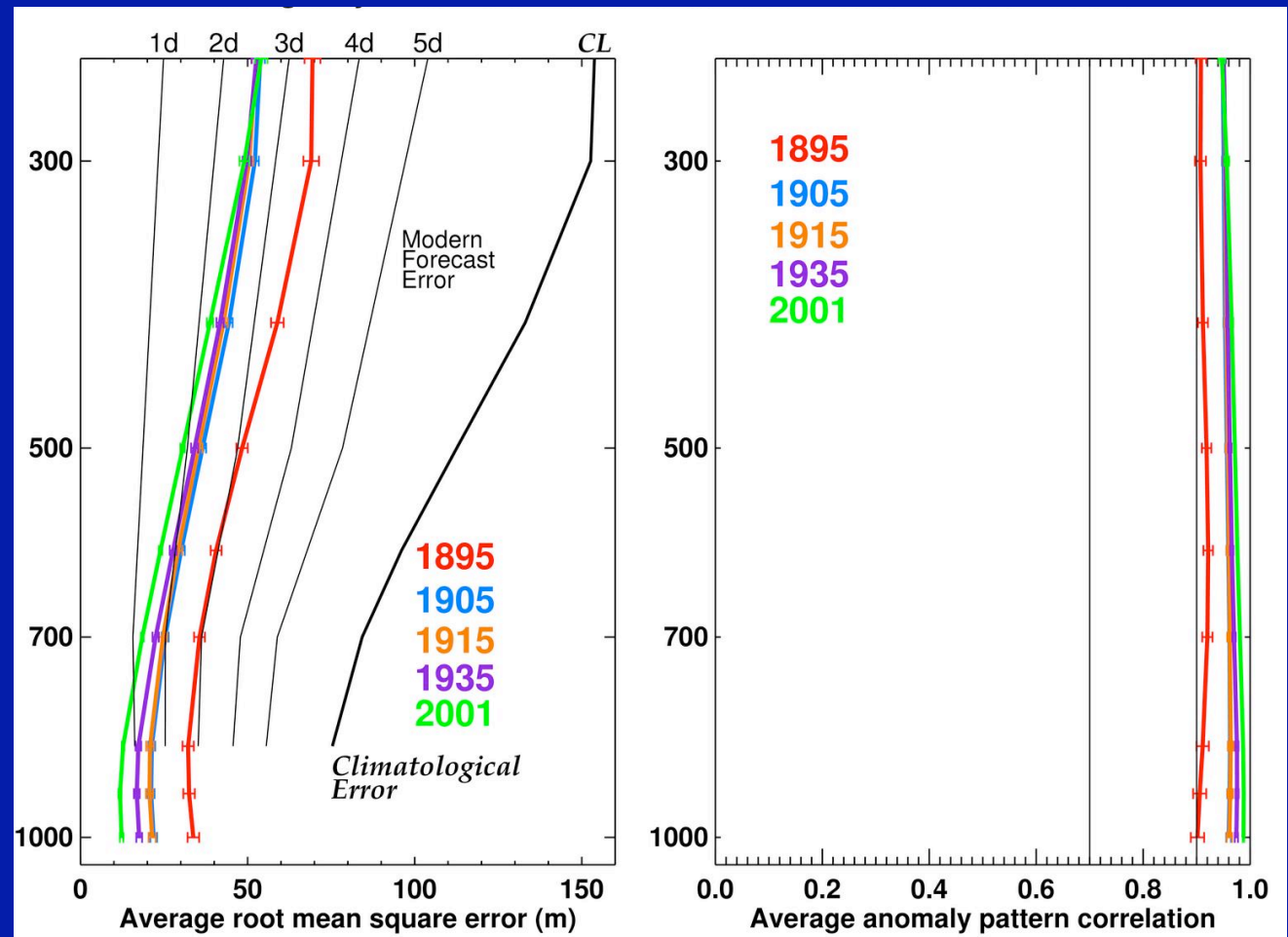
RMS Error and Anomaly Correlation skill of  
6-hourly geopotential height analyses using Ensemble Filter and  
Only Surface Pressure Obs at 1895, 1905, 1915, 1935, and 2001 densities

RMS

anomaly correlation

Increasing  
number and  
coverage of  
observations  
will help greatly  
for 1895 period.

1905 only has  
30 obs more per  
analysis, but  
much better  
coverage.



Simulating December 2001

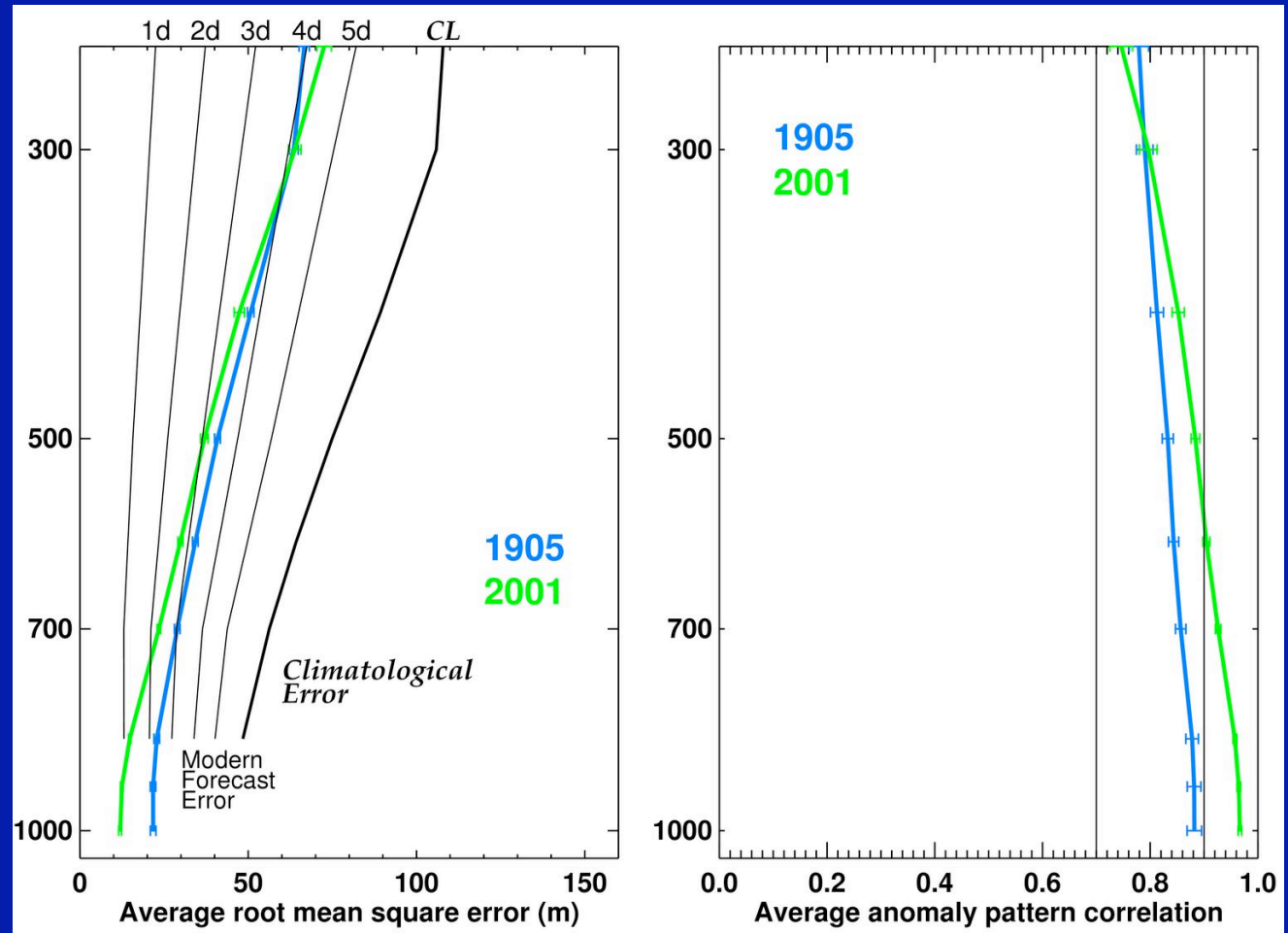


**RMS Error and Anomaly Correlation skill of 6-hourly geopotential height  
analyses for Northern Hemisphere June 2001 using Ensemble Filter and  
Only Surface Pressure Obs at 1905 and 2001 densities**

RMS

anomaly correlation

Increasing number  
and coverage of  
observations will  
help lower  
tropospheric  
analysis of early  
20<sup>th</sup> century.



# The 20th Century Reanalysis Project

**Summary:** An international collaborative project led by NOAA to produce high-quality tropospheric reanalyses for the last 100 years *using only surface observations*.

The reanalyses would provide:

- First-ever estimates of near-surface and tropospheric 6-hourly fields extending back to the beginning of the 20<sup>th</sup> century;
- Estimates of biases and uncertainties in the basic reanalyses;
- Estimates of biases and uncertainties in derived quantities (storm tracks, etc.)

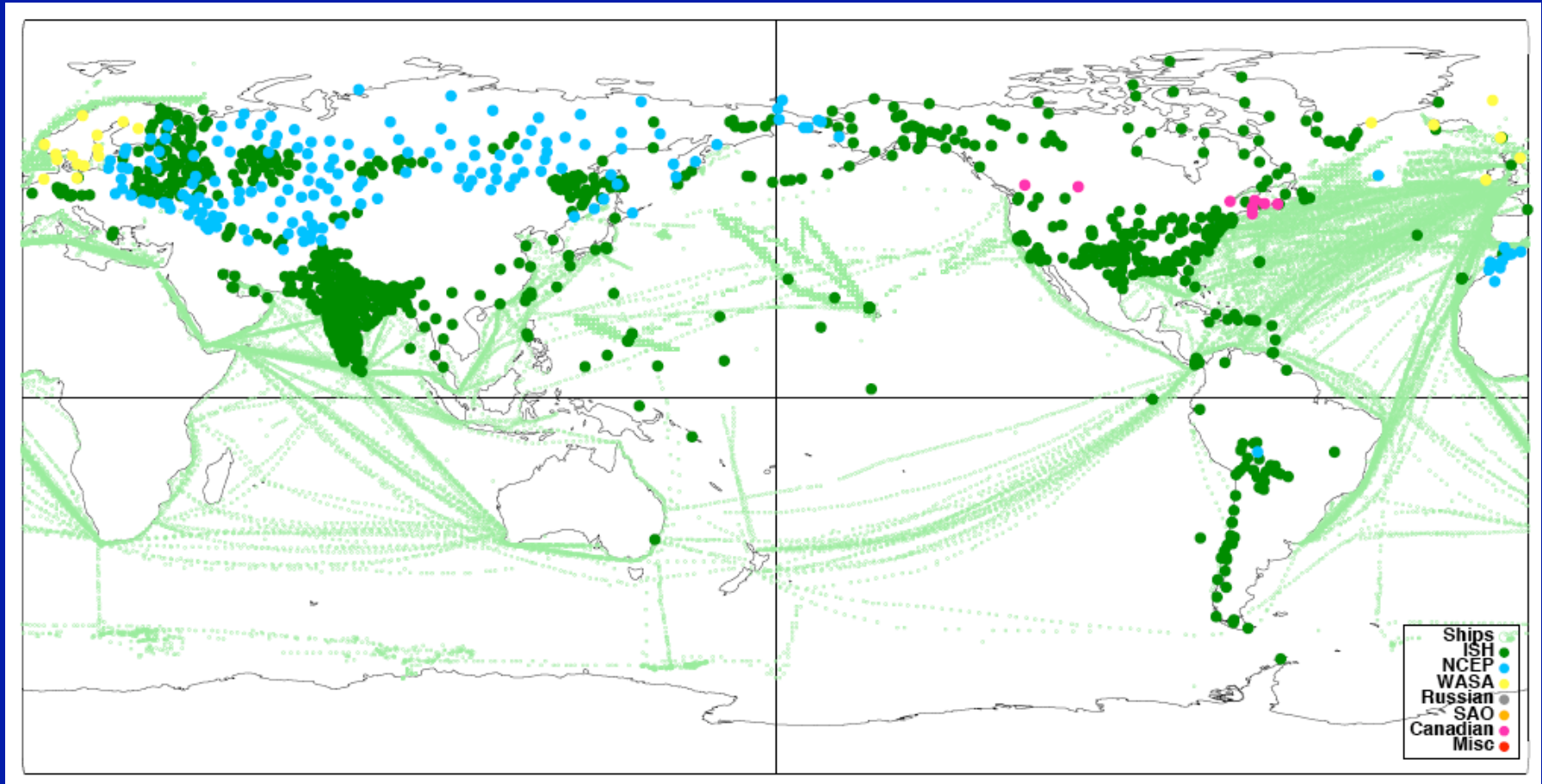
Initial product would have higher quality in the Northern Hemisphere than in the Southern Hemisphere.

**Proof of concept for 1938-1948.**  
**Initially test 1947.**

**Partners:** All Union Research Institute of Hydrometeorological Information – WDC; Australian Bureau of Meteorology; EMULATE; Environment Canada; ETH-Zurich; Hong Kong Observatory; ICOADS; KNMI; MeteoFrance; National Center for Atmospheric Research; NOAA ESRL, NCDC, NCEP, CDMP; UK Hadley Centre; U. of Colorado-CIRES; U. of East Anglia-CRU



# Pressure Observation locations Nov-Dec 1947



Pilot reanalysis:

NCEP model: Global Forecast System 2003 T62L28

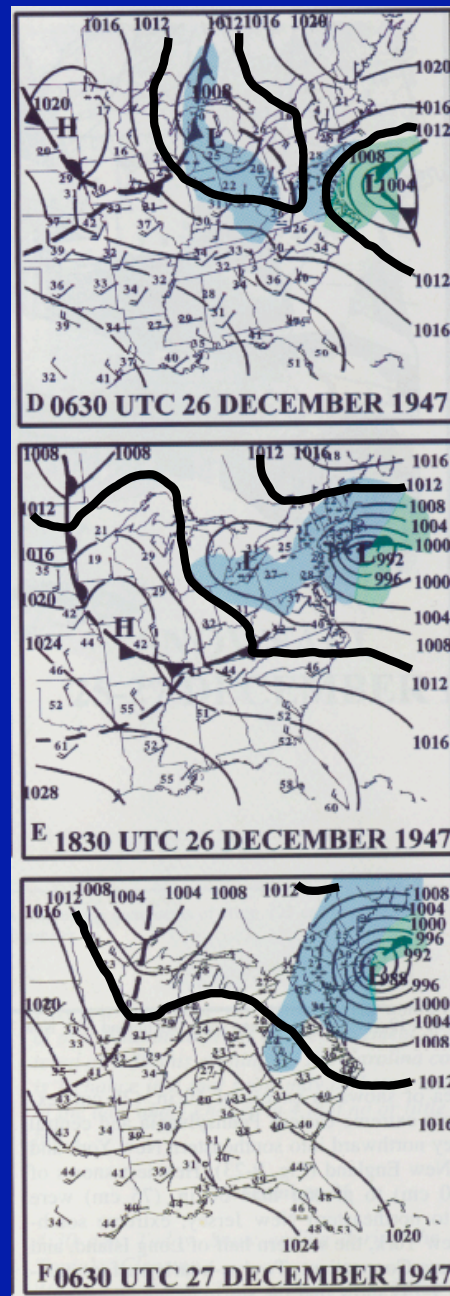
Ensemble Filter with 6-hour window using covariances with correct time  
(4-D approach)

# Sea Level Pressure Analyses 26 - 27 December 1947

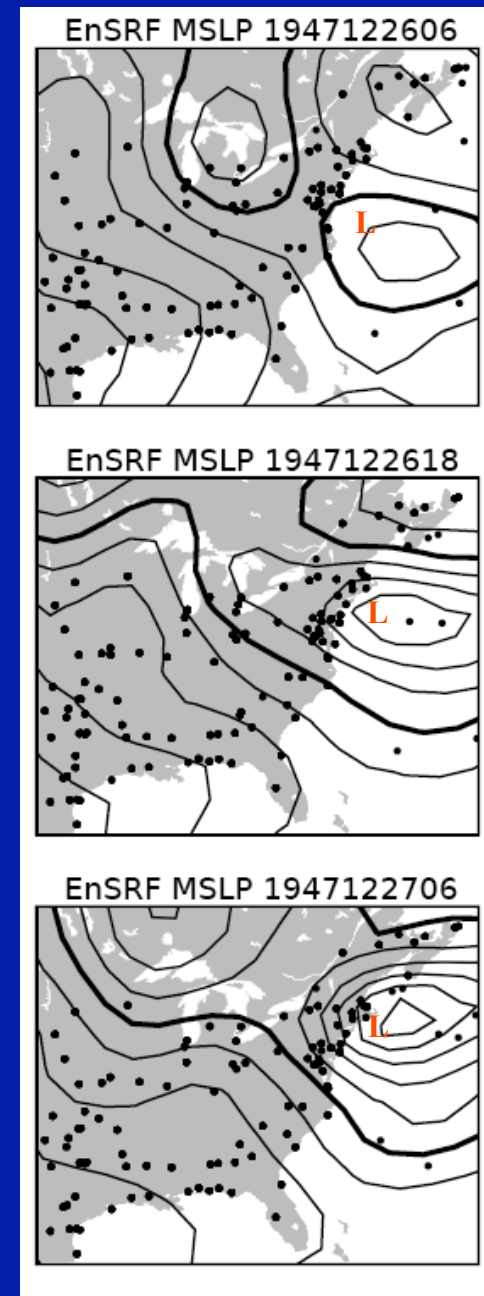
Intensity of East Coast Low is weaker in Ensemble Filter analyses, but major features are present.

Contour interval is 4 hPa in all panels and 1012 hPa contour is thickened.

(Kocin and Uccellini, 2004)



US Weather Bureau



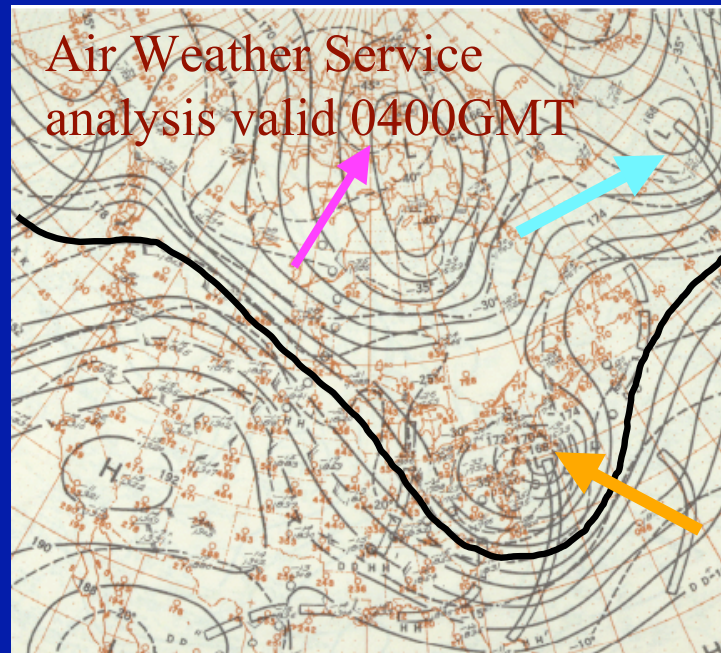
Ensemble Filter



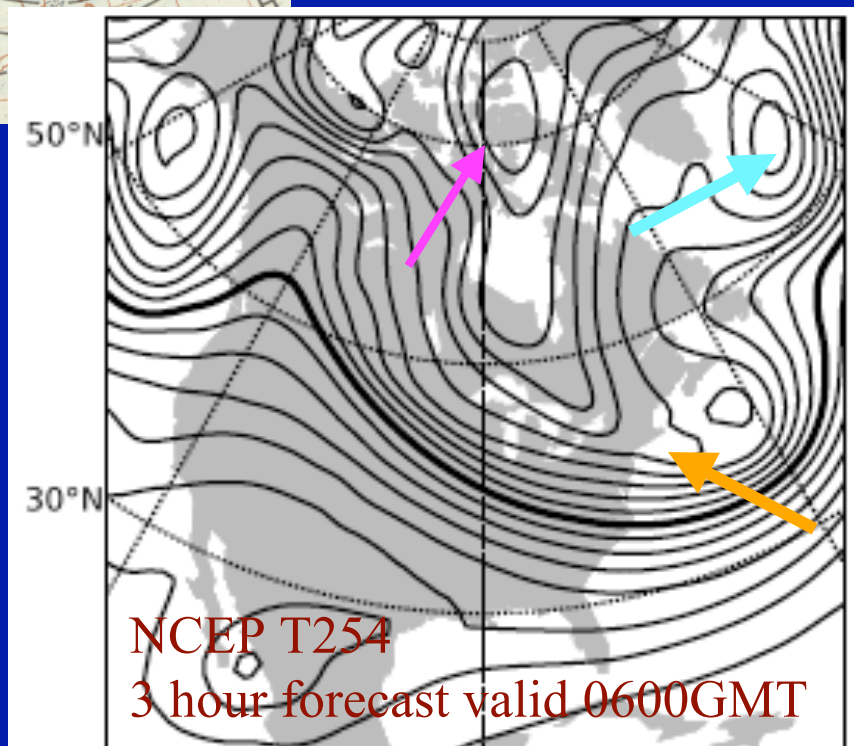
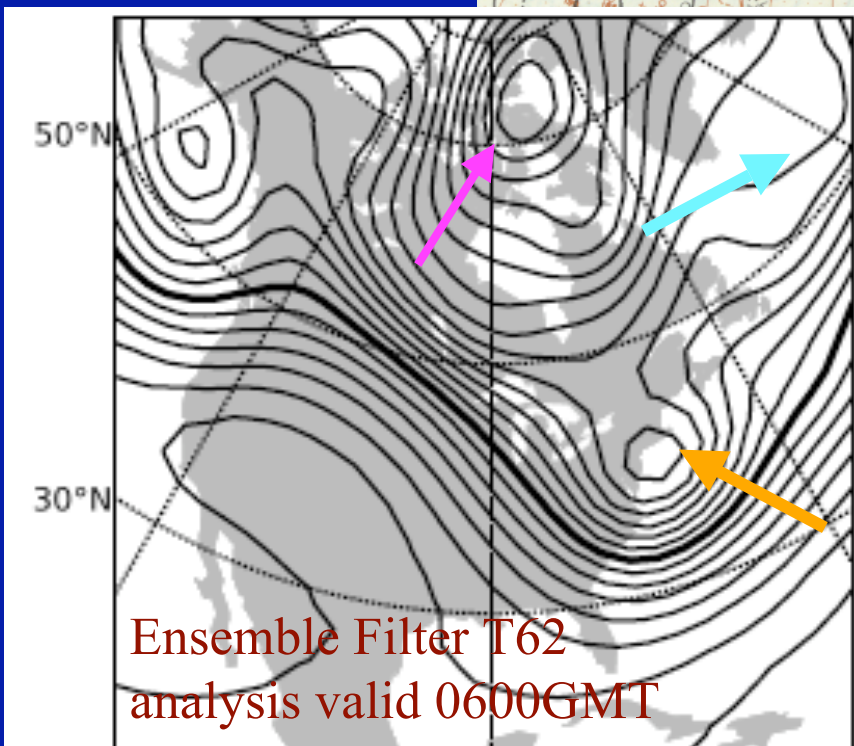
# 500 hPa geopotential height

27 December 1947

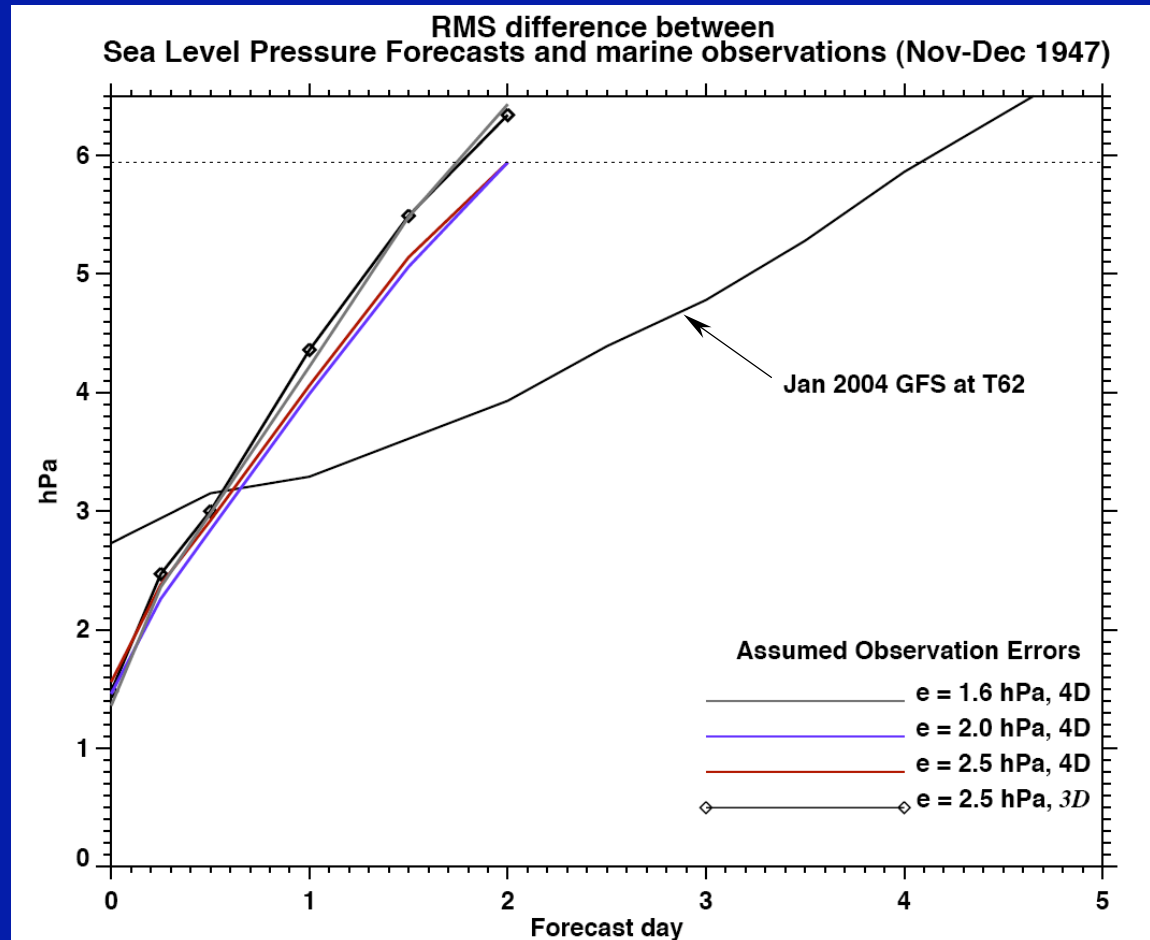
5500 m (18000 ft)  
contour is thickened



Ensemble Filter  
analysis has comparable  
quality to NCEP 3D-VAR



# RMS difference of SLP forecasts with marine SLP observations



Marine SLP observation error of 2.0-2.5 hPa and 4-D approach give best 2-day forecasts.

2-day forecast error for 1947 using only pressure observations is comparable to 4-day error in 2004 using all observations.

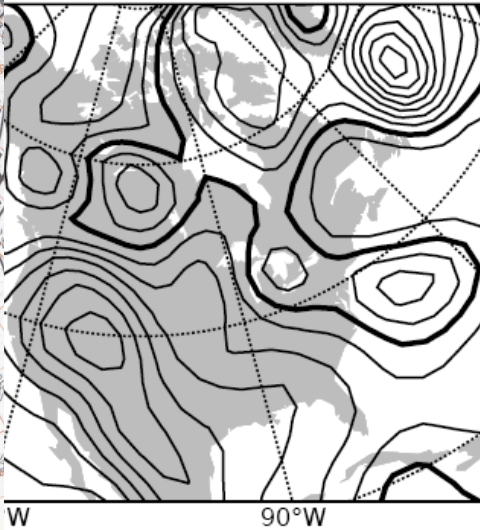
## Conclusion- The 20th Century Reanalysis Project is Feasible !!

1. Reanalyzing the lower-tropospheric circulation of the entire 20<sup>th</sup> century is feasible in the Northern Hemisphere *using just the available surface observations*.
2. Better methods than 3d-Var will produce better results, especially in the *upper* troposphere.
3. Keying or exchanging additional marine observations will greatly increase the fidelity of the reanalysis and give errors comparable to current 2-3 day forecasts.
4. Results using 1947 surface pressure observations suggest that these feasibility conclusions are realistic.

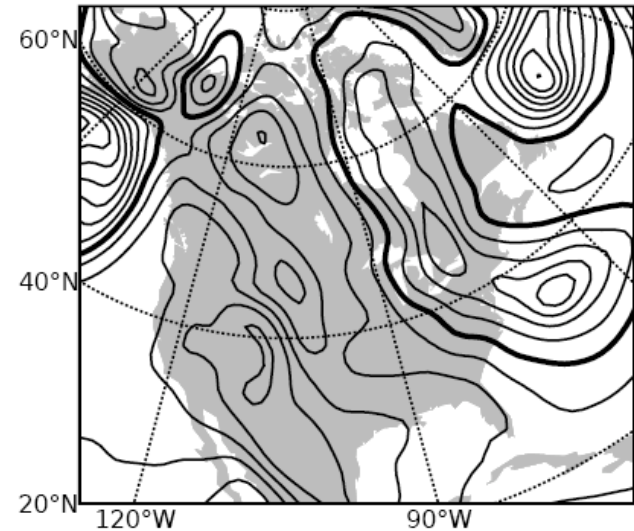
# SLP 26 Dec 12Z



RF MSLP analysis 1947122612

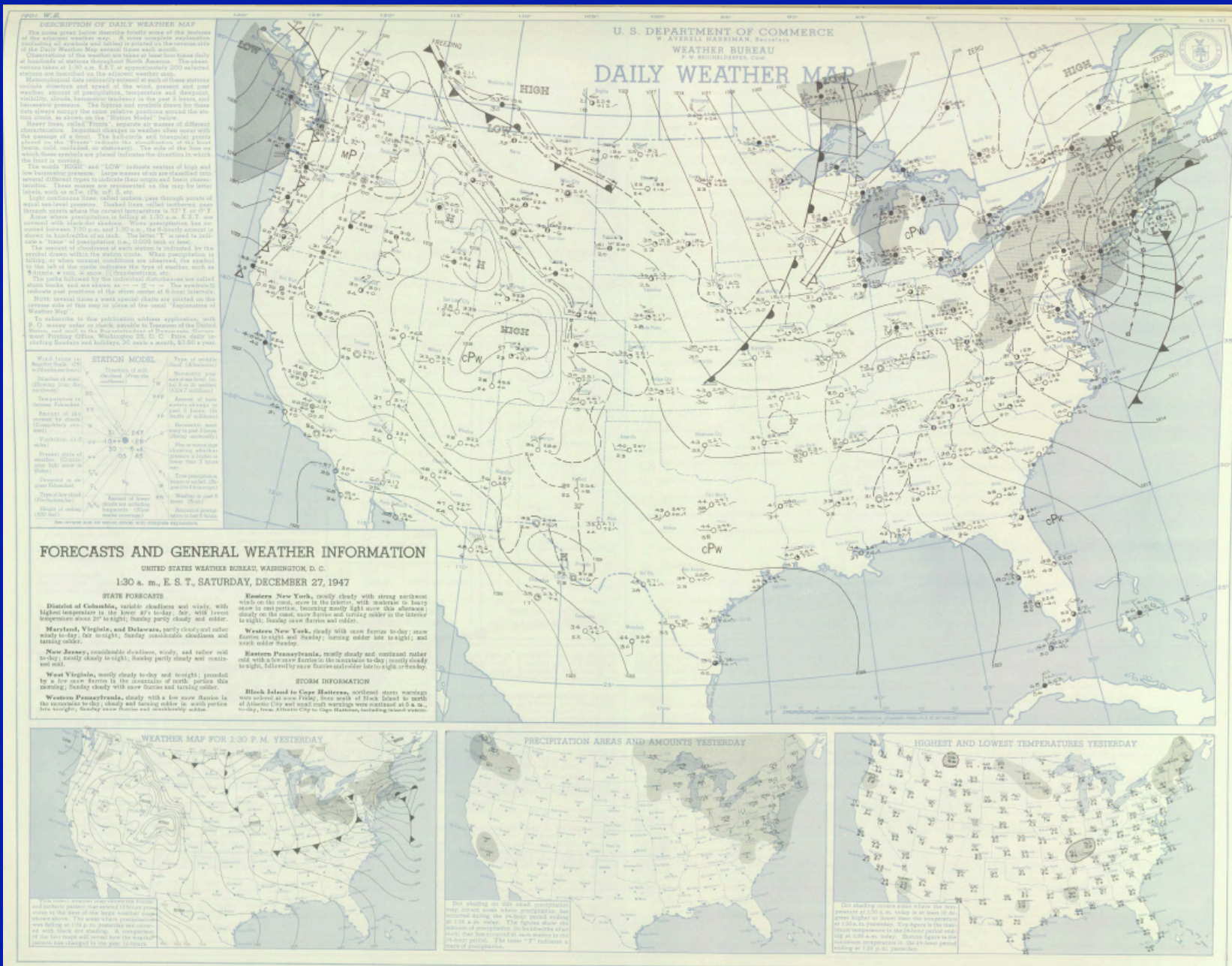


NCEP MSLP 3-h fcst valid 1947122612



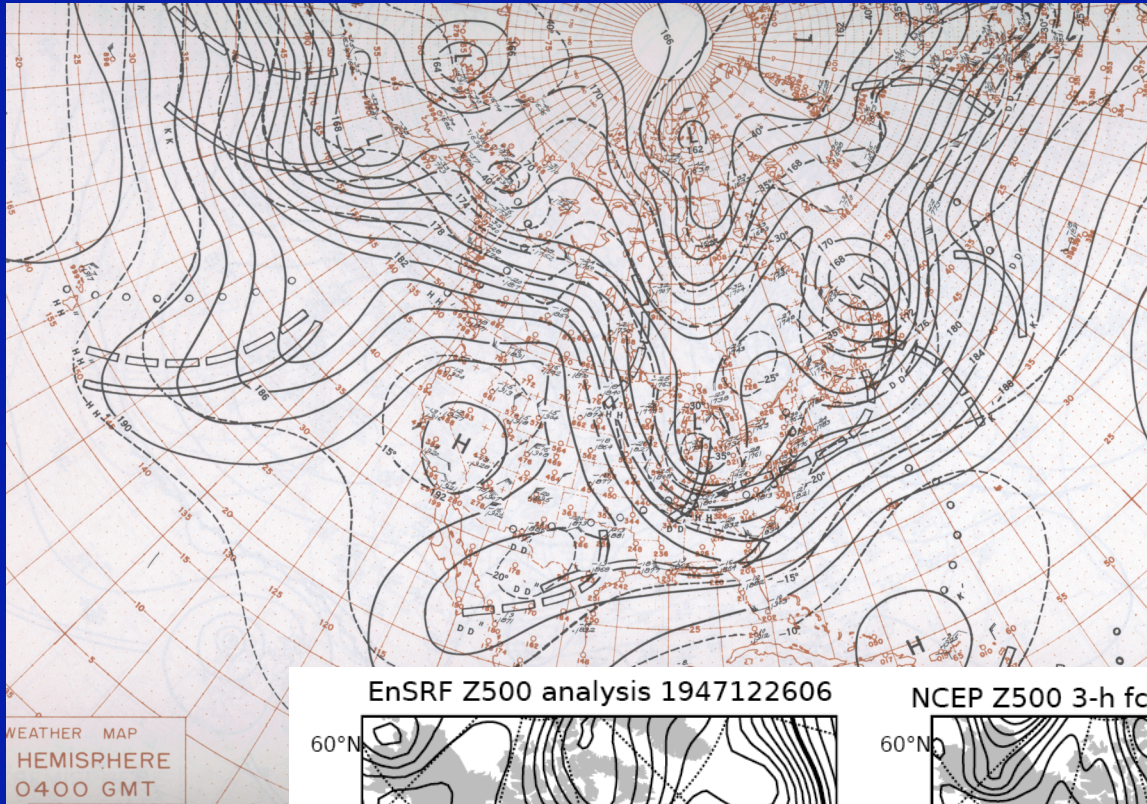


## Sea Level Pressure Analysis 27 December 1947 0630 GMT

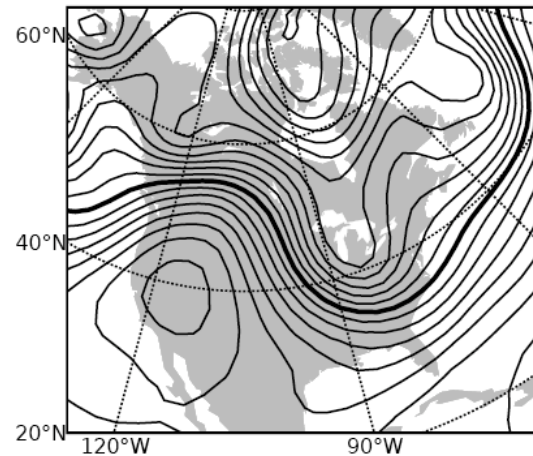




# 500 hPa geopotential height analyses 26 December 1947 04Z



EnSRF Z500 analysis 1947122606



NCEP Z500 3-h fcst valid 1947122606

